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Study of surface ozone at Port Blair, India, a remote marine station in the Bay of Bengal

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ABSTRACT

This paper presents seasonal variation of surface ozone monitored continuously at site of the meteorological observatory at Port Blair, a maritime site of the Bay of Bengal for the period of August, 2005–March, 2007. Present observation depicts the characteristics of surface ozone at the remote marine site and the long range transport of pollutants from three different sides i.e., Indian Subcontinent, South East Asia and Indian Ocean. Very high ozone mixing ratio (~70–80 ppbv) is occasionally observed during March and November at this site. A campaign mode of observation of trace gases (surface ozone, CO, NO_x, CO_2), aerosol concentration and its size, UV radiation at Port Blair was made to understand the role of transport on pollutants during March 16–26, 2002. During this period of observation, a near zero surface ozone of different time scales (~few hours) has been observed several times during the period of midnight to early morning. Simultaneously NO_x ($NO+NO_2$) (~40 ppbv) and carbon monoxide was observed very high (300–600 ppbv) during this period. Source of this high pollutant are not expected at this remote marine sites although wind patterns, 7-days isentropic back Trajectory analysis and MATCH Model output suggest that polluted air mass has come from eastern side of Indian subcontinent.

1. Introduction

Due to fast economic growth, emissions of particulate matter and trace gases (Ohara et al., 2007) might have provided enormous impact on the Southeast Asia and its surroundings (Lawrence and Lelieveld, 2010). Due to the emission of precursor gases, tropospheric ozone may increase significantly in future in this part of the world (Lelieveld et al., 2001; Yamaji et al., 2008). Observation of large haze over Indian Ocean observed during the Indian Ocean Experiment (INDOEX), has necessitated more observations at remote sites, where local sources are possibly less, to understand the characteristics of transports of pollutants ranging from local to trans-boundary (Ramanathan et al., 2001).

Tropospheric ozone, a toxic gas, plays role in radiative balance and also in the tropospheric chemistry (Crutzen et al., 1999). A remote marine place, Port Blair, is generally influenced by three types of flows i.e., originated from clean Indian Ocean, Indian subcontinent, South-East Asian. It is the only station in the Indian subcontinent to catch the effect of biomass burning of East Asia. Generally, observation of surface ozone done in campaign mode over the remote Arabian Sea, Bay of Bengal and Indian Ocean, is reported so far (Lal et al., 1998; Sahu and Lal, 2006; Lal and Lawrence, 2001; Chand et al., 2003). Several authors (Chand et al., 2003; Nair et al., 2013; Lal et al., 2001 and Ali et al., 2009) have reported the surface ozone variation over Arabian Sea in different seasons. Chand et al. (2003) have shown those variations of ozone in the marine boundary layer over the Arabian Sea and the Indian Ocean during the 1998 and 1999 INDOEX campaigns. Nair et al. (2013) have reported the O_3 mixing ratio over the Arabian Sea prior the monsoon, which varied in the range ~3–22 ppb with a mean of 13.5 ± 2 ppb. Lal et al. (2001) have shown that surface O_3 levels exceeding 70 ppbv, the highest observed to date over the Indian Ocean, were recorded in the Arabian Sea marine boundary layer during the Indian Ocean Experiment (INDOEX) in 1999. They have connected the elevated mixing ratio to the advection process of continental surface ozone. Ali et al. (2009) have shown that during southwest monsoon low surface ozone by reactive halides released from sea salt aerosols is the sink mechanism which played a crucial role in ensuring the significantly low ozone level over the Arabian Sea.

The measurements over the BoB have ensued since the "Indian Ocean Experiment" (INDOEX). (Lelieveld et al., 2001; Muhle et al., 2002). During INDOEX, O_3 levels over the BoB sometimes exceeded the levels in nearby coastal cities, highlighting the

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complexity of chemistry and dynamics over this region. The INDOEX-99 revealed two major pathways for South Asian pollutants to the Indian Ocean: first one from the Indo-Gangetic Plain (IGP) via the BoB and second one from Southwest Asia via the Arabian Sea (Ramanathan et al., 1996). Higher levels of pollution over the BoB compared to the Arabian Sea highlighted the importance of this marine region in influencing the tropical chemistry. Detailed chemical study of BoB air masses was first attempted through the "Bay of Bengal Experiment" (BOBEX I) when measurements of O_3, methane (CH4), carbon monoxide (CO), and sulfur hexafluoride were made during February–March 2001 (Lal et al., 2006). High levels of O_3 (> 60 ppbv), observed over the central BoB (10 °N–14 °N) during BOBEX I, were traced to Bangladesh and Myanmar regions. Measurements of nonmethane hydrocarbons (NMHCs) over the BoB were initiated during the "Bay of Bengal Process Studies" (BOBPS) in September–October 2002 (Sahu and Lal, 2006). Subsequent measurements, made during February 2003 (BOBEX II) (Lal et al., 2007), enabled characterization of air masses using trace gas ratios. Strong correlations of ethane and acetylene with carbon monoxide (CO) provided chemical evidence of transport of anthropogenic emissions into the MABL. The spatio-temporal heterogeneity and effects of continental transport on the surface and vertical distributions of trace gases over the BoB were investigated further during the "Integrated Campaign for Aerosols, gases and Radiation Budget" (ICARB) during March–May 2006 (Srivastava et al., 2011, 2012). The ICARB results were useful to actually quantify the impacts of various source regions on O_3 distributions over the BoB. Further, surface measurements of O_3, CO, and nitrogen dioxide (NO_2) were accompanied by airborne measurements of O_3 and NMHCs during the winter phase of ICARB (W-ICARB) during December 2008 to January 2009 (Asatar and Nair, 2010; David and Nair, 2011). While there have already been a few campaigns to study trace gas variability over the BoB, measurements had been lacking during monsoon (June, July, and August) and later half of post monsoon (October and November) periods. The present study is aimed at reducing this temporal gap through reporting of extensive measurements of O_3 along with its several precursors during October–November 2010.

The observations of surface ozone are available at different sites at metro cities or rural sites of India (Naja and Lal, 1996; Singh et al., 1997; Lal et al., 2000; Reddy et al., 2010). No such long term measurement of surface ozone is available at the remote marine site.

The objective of this paper is to study the behavior of surface ozone and meteorological parameters at a remote marine site in the Bay of Bengal. Short term relationship of precursor gases (CO, NO_x) with surface ozone has also been identified with possible link to long range transport.

2. Observation sites and techniques

2.1. Site description

Observations of trace gases including surface ozone are made at the meteorological observatory of Port Blair (11°40′N 92°45′E) (Fig. 1). The observational site is on the top of the hilly area keeping the local airport in the western direction and is just 10 km in the eastern coast of Port Blair. Although total pollution of Port Blair is of the order of few thousands, residential activity around the observation site is very sparse, which ruled out the local influences. Port Blair is the largest town in the Andaman Islands and the capital of the Andaman and Nicobar Islands union territory of India. It lies on the east coast of South Andaman Island and is the main entry point to the islands. Andaman and Nicobar groups of islands are situated in the Bay of Bengal, mid way between

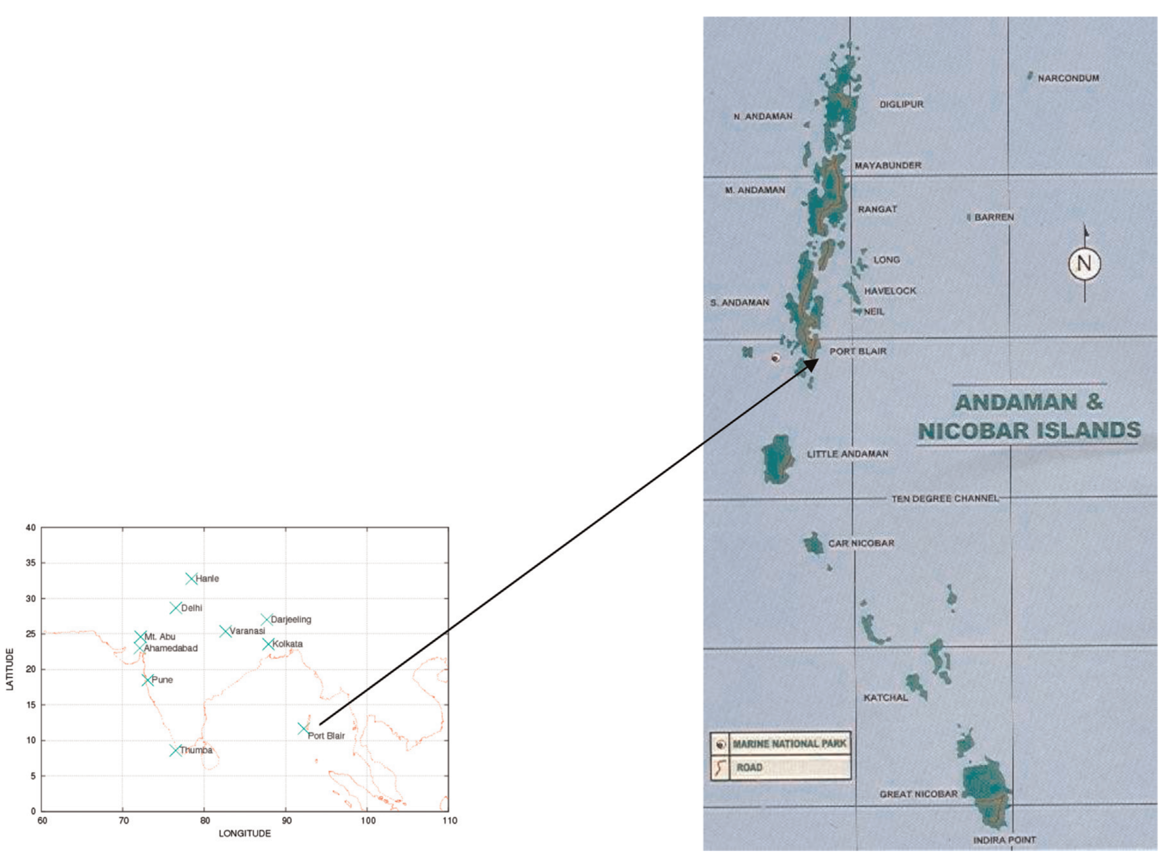

Fig. 1. Location of Port Blair. Inset map of India.